A. Cover Page

1. Project Title

Developing a decision support tool for processing tomato irrigation and fertilization in the Central Valley based on CropManage

2. Project Leaders

Daniel Geisseler, CE Nutrient Management Specialist, University of California, Department of Land, Air and Water Resources, One Shields Ave., Davis, CA, 95616. (530) 754 9637, djgeisseler@ucdavis.edu

3. Cooperators

Tim Hartz, CE Specialist/Agronomist, University of California, Department of Plant Sciences, One Shields Ave., Davis, CA, 95616. (530) 752 1738, tkhartz@ucdavis.edu

Gene Miyao, UCCE Farm Advisor, Yolo, Solano & Sacramento counties, 70 Cottonwood Street, Woodland, CA, 95695. (530) 666-8732, emmiyao@ucanr.edu

Mark Lundy, UCCE Farm Advisor, Colusa, Sutter and Yuba counties, PO Box 180, 100 Sunrise Boulevard, Suite E, Colusa, CA, 95932. (530) 902 7295, melundy@ucanr.edu

Tom Turini, UCCE Farm Advisor Fresno County, 550 E. Shaw Avenue, Suite 210-B, Fresno, CA, 93710. (559) 241-7529, taturini@ucanr.edu

Brenna Aegerter, UCCE Farm Advisor San Joaquin County, 2101 East Earhart Ave, Suite 200, Stockton, CA, 95206. (209) 953-6114, bjaegerter@ucanr.edu

Mike Cahn, UCCE Farm Advisor Monterey County, 1432 Abbott Street, Salinas, CA, 93901. (831) 759-7377, mdcahn@ucanr.edu

5. CDFA Funding Request Amount/Other Funding

	CDFA Funding Request	Other Funding
2016:	74,888.65	4,130.00
2017:	74,907.98	1,500.00
2018:	74,920.06	500.00
Total:	**224,716.69**	**6,130.00**

6. Agreement Manager

Randi L. Jenkins, Associate Director, The Regents of the University of California, Sponsored Programs. 1850 Research Park Drive, Suite 300, Davis, CA 95618-6153. (530) 754 7700, awards@ucdavis.edu

B. Executive Summary (not to exceed two pages)

1. Problem

California growers are facing increasing pressure to improve nitrogen (N) use efficiency in crop production. To achieve high yields while reducing the risk of N losses, the time and quantity of irrigation water and fertilizer applications need to match crop demand. Adjustments to general irrigation and fertilization guidelines are generally needed on a field-by-field basis.

Processing tomatoes are an important California crop grown on about 288,000 acres in 2014. Over the last 15 years, the tomato industry saw a dramatic shift in production practices caused by a wide adoption of drip irrigation. During the same period, tomato yields increased from roughly 36 tons/acre to almost 50 tons/acre. This rapid shift from predominantly furrow irrigation to drip irrigation and the associated yield increase changed N fertilizer management considerably, with fertigation through the drip system now being most common.

With stricter regulatory and reporting requirements and technological advances, which provide growers with more accurate but also increased amounts of data, computer based decision support tools are becoming a central component of farm management.

The project proposes to develop such a decision support tool for irrigation and N management in processing tomatoes based on the framework of an existing tool, CropManage, which has been successfully developed and introduced for cool season vegetables on the Central Coast. The proposed project also includes outreach activities, including workshops to train growers and consultants (i.e. CCAs) in the use of the modified program developed for tomatoes.

2. Objectives, Approach, and Evaluation

Objectives

The main objective is to develop a web-based decision support tool for improved N and irrigation management of processing tomatoes. The specific objectives are:

1. Create a test version of CropManage for processing tomato production in the Central Valley based on literature data.
2. Collect soil and plant related data in commercial fields to develop robust equations and algorithms for user version of the program.
3. Compare irrigation and fertigation management recommended by the program with grower's practices in a replicated trial at UC Davis' Russell Ranch.
4. Evaluate the program in monitoring fields in close collaboration with participating growers.
5. Develop the user version of CropManage based on the data collected and feedback received in objectives 2 through 4.
6. Conduct outreach activities and organize training workshops for growers and consultants.

Approach

A decision support tool for processing tomatoes based on CropManage will be developed. Initially, a test version will be created using published data. During the first year of the project, the test version will be evaluated in commercial fields. Crop development, residual soil nitrate

and other soil properties will be monitored in these fields located in the Sacramento Valley, the northern San Joaquin Valley and the central San Joaquin Valley. The collected data will serve to improve the equations and algorithms of the program. The improved version of the program will be evaluated during the second year of the project in a different set of monitoring fields. In addition, a replicated trial at Russell Ranch, west of UC Davis, will be carried out to compare irrigation and fertilization schedules recommended by the program with common grower practices. The data collected during the second year will be used to further improve the equations and algorithms of the program. In addition, the experience gained by using the program during the first two years, including grower feedback, will be used to improve the user interface.

During the winter following the second year of the project, training sessions for interested growers and consultants will be offered at different locations in the Sacramento and San Joaquin valleys. In these sessions, CropManage for processing tomatoes will be introduced and growers will be trained in the use of the program. In addition, follow-up meetings will be held during the growing season to address problems and questions. A survey will be carried out in fall 2018 to receive a feedback from the participants about their experience. Training sessions for a second group of interested growers and consultants will be scheduled for winter 2018/19 and training and information events will continue beyond the projects duration depending on interest.

Other outreach activities include presentation of the results at workshops and seminars and in newsletters and articles. The results will also be used to update the online fertilization guidelines hosted on the FREP website.

Evaluation

A major milestone of the project is the release of CropManage for processing tomatoes. We expect to release a version of CropManage for processing tomatoes that is ready to be used by growers in the winter 2017/18.

We expect that using the tool at the replicated trial at Russell Range to guide irrigation and fertigation decisions will result in significantly increased water and N use efficiency without reducing yield compared to grower practices.

The success of the project will also be determined by the number of growers and consultants attending the training workshops and the number of growers and consultants registering to use CropManage for tomatoes. We expect that a total of at least 20 growers and consultants will attend the training sessions each year and that at least 75% of the participants in 2017/18 will continue using CropManage beyond the 2018 growing season.

3. Audience

The beneficiaries of this project are the approximately 275 enterprises producing processing tomatoes in California on 288,000 acres of cropland as well as consultants working with processing tomato producers. Increased N and irrigation water use efficiency will reduce the risk of nitrate leaching to the groundwater and may have economic benefits for growers as higher yields may be achieved through improved timing of N applications or production costs may be lowered if overall N application rates can be reduced.

Modules developed during this project may also be used when CropManage is adapted to other crops grown in the Central Valley.

C. Justification

1. Problem

California growers are facing increasing pressure to improve N use efficiency in crop production. To achieve high yields while reducing the risk of N losses, the time and quantity of irrigation water and fertilizer applications need to match crop demand. Adjustments to general irrigation and fertilization guidelines are generally needed on a field-by-field basis. Field-specific management needs to take into consideration the temporal pattern of N availability and crop N demand. Effective implementation of field-specific management will require expanded outreach to the industry, and the development of decision support tools that will streamline the management of complex data sets.

Processing tomatoes are an important California crop grown on about 288,000 acres in 2014 (USDA NASS, 2015). Over the last 15 years, the tomato industry saw a dramatic shift in production practices caused by a wide adoption of drip irrigation. While less than 10% of the acreage was drip irrigated in 1999, this number has reached 85% in 2012 (Taylor et al., 2014). During the same period, tomato yields increased from roughly 36 tons/acre to almost 50 tons/acre. This rapid shift form predominantly furrow irrigation to drip irrigation and the associated yield increase changed fertilization management considerably, with fertigation through the drip system now being most common. These high yields are only possible with an adequate N supply. However, inappropriate N fertilization raises the risks of nitrate leaching to groundwater, nitrous oxide emissions, and increases costs of production. Furthermore, recent studies in commercial processing tomato fields have revealed that residual soil nitrate concentrations before transplanting seedlings can vary considerably, with nitrate-N values ranging from less than 30 to more than 200 lbs/acre in the top two feet of the profile (Martin Burger, personal communication). These results highlight the need for field-specific nutrient management.

Processing tomato growers are very interested in decision support tools. At the lower Sacramento Valley Processing Tomato Production Meeting in January 2015, attendees were asked to answer a few questions on a questionnaire to assess their interest in a computer based decision support tool. Interest in a decision support tool was large, especially among growers. Out of the 21 growers who returned the questionnaire, 20 and 19 responded that such a decision support tool would be valuable for irrigation and N management, respectively. Fifteen growers also responded that a decision support tool would be valuable for record keeping. Growers attending a meeting in Modesto, held in late January, also showed a very high interest in a decision support tool. Only one out of 30 growers participating responded that a tool was not necessary. For this group of growers, a tool would be most useful for irrigation management (25 responses), followed by N management (19 responses) and record keeping (15 responses).

The project proposes to develop such a decision support tool for processing tomatoes based on the framework of an existing tool, CropManage, which has been successfully developed and introduced for cool season vegetables on the Central Coast. The proposed project also includes outreach activities, including workshops to train growers in the use of the tool developed.

2. FREP Mission and Research Priorities

The proposed project addresses the FREP special research priority "*Developing Integrated Water and Nutrient Management Tools*" by creating a web-based decision support tool for

processing tomatoes. Local weather data, crop development, soil fertility, as well as soil and water monitoring technologies will be integrated into a user-friendly tool to optimize irrigation scheduling and fertigation practices.

3. Impact

The beneficiaries of this project are the approximately 275 enterprises producing processing tomatoes in California on 288,000 acres of cropland (USDA NASS, 2015). The decision support tool we propose to develop will facilitate record keeping and make in-season recommendations for irrigation and N fertilization based on current weather data and field-specific factors. Growers and consultants choosing not to use CropManage for their fields will also benefit from the data collected and presented at outreach events, allowing them to improve water and N use efficiency in their fields.

In the long term, the results of this project and the successful adoption of the program by growers have the potential to reduce nitrate leaching and gaseous N losses, and this would help preserve groundwater and air quality in the Central Valley and thus benefit the estimated 12 million people living there by 2040. In addition, growers will benefit economically, as the program will likely increase yields through improved timing of N applications and production costs may be lowered if overall N application rates can be reduced.

Modules of the tool developed during the proposed project can be used to adapt CropManage to other crops grown in the Central Valley.

4. Long-Term Solutions

CropManage for processing tomatoes will support growers making irrigation and fertigation decisions based on the most current research findings, weather conditions and field-specific data. Using the program potentially increases water and N use efficiency, resulting in lower risks of nitrate leaching to the groundwater. The program also facilitates record keeping and comparisons of management and crop performance between fields and across years. Even growers who choose not to use the tool will benefit from the planned outreach activities, such as presentations and newsletter articles.

With stricter regulatory and reporting requirements and technological advances, which provide growers with more accurate but also increased amounts of data, computer based decision support tools are becoming a central component of farm management. CropManage for processing tomatoes will facilitate complying with regulatory and reporting requirements and allow growers to take advantage of new developments, such as flow meters and soil moisture sensors connected to wireless transmitters, and incorporate the data generated into their decision making process.

5. Related Research

This project builds on previous research and outreach efforts, many of which received FREP support.

CropManage: The decision support tool for tomatoes will be based on CropManage. CropManage is an online database-driven tool that assists growers and farm managers in determining water and N fertilizer applications on a field-by-field basis (Cahn, 2012).

CropManage integrates CIMIS reference ET data and field specific soil, plant and management information to calculate crop water needs and estimates fertilizer N needs. The software was developed by UC Cooperative Extension, is free to use and can be accessed with a web browser using a smart phone, laptop, or tablet computer (Cahn, 2012).

Initially created for lettuce production on the Central Coast, the program has now been adapted for other cool season crops and strawberries. More than 350 individuals have registered to use CropManage and current users have added more than 100 ranches to the database (Cahn, personal communication). A current project is further expanding the number of vegetable crops CropManage can support.

Adapting CropManage to tomato production instead of developing an entirely new decision support tool will reduce time and costs of development considerably. Furthermore, a tool that can be used for many different crops is more attractive for growers, as it can be used for fields with crop rotations. Adapting CropManage to crops grown in the Central Valley increases the chances that CropManage will become the standard decision support tool for irrigation and fertilization management in California.

Field trials: Several research projects have been carried out over the last few years to investigate irrigation and nutrient management practices in processing tomatoes.

In a study in six commercial fields, growers applied on average 186 lbs N/acre, with values ranging from 170 to 215 lbs N/acre. Total uptake in these fields was 240 lbs/acre, and total N removed reached 170 lbs/acre, which corresponded to 71% of total uptake (Hartz, 2009; Hartz and Bottoms, 2009). In a study in 8 commercial fields southwest of Fresno, Hanson and May (2006) determined crop coefficients and canopy coverage of drip and furrow irrigated tomatoes. Crop evapotranspiration (ET_c) averaged 27.4 inches for drip irrigated tomatoes.

The results from these studies will be used to create a test version of CropManage for processing tomatoes (see Task 1). The grower application rates will also be used as the control treatment in the replicated trial (see Task 3). For the final version of the project, additional research will be needed (See Task 2). While the study by Hanson and May (2006) generated an extensive dataset of canopy development over time, all the work was done in fields near the Westside Field Station; other geographical locations need coverage as well. Counting published and unpublished research, total N uptake and partitioning has been determined in a relatively large number of fields. However, in only a fraction of those has the pattern of N uptake over the season been determined by sequential destructive sampling (Hartz and Bottoms, 2009). A more robust dataset from fields in different regions of California is needed to develop an accurate final version of CropManage for processing tomatoes.

Fertilization Guidelines: The available literature about fertilization management of processing tomatoes has recently been summarized in a FREP supported project and made available online in the form of user-friendly fertilization guidelines (http://apps.cdfa.ca.gov/frep/docs/Tomato.html). The guidelines will be used for discussions with growers about optimal management practices.

6. Contribution to Knowledge Base

The project will generate a robust dataset for tomato growth, seasonal N uptake and N removal at harvest based on samples taken from commercial fields in the Sacramento and San Joaquin valleys. The data will be used to develop a tomato-specific version of CropManage, allowing growers to apply the most recent research-based information on a field-specific basis.

The results of the project will be presented at a number of outreach events and in newsletters to disseminate the information to growers and consultants. Furthermore, the collaborating farm advisors will use the information from this project for their work with tomato growers. This will ensure that growers who chose not to use the program will also benefit from the data generated.

7. Grower Use

The decision support tool will be free to use. It will help growers and consultants keep track of irrigation water and fertilizer applications and thus facilitate field-specific fertilization and irrigation practices. The tool will provide growers the most recent research-based information in a user-friendly way to support field-specific irrigation and fertilization decisions. Furthermore, using the program will facilitate record keeping for reporting and retrospective evaluation of irrigation and nutrient management.

D. Objectives

The main objective is to develop a web-based decision support tool a web-based decision support tool for improved nutrient and irrigation management of processing tomatoes.

The specific objectives are:

1. Create a test version of CropManage for processing tomato production in the Central Valley based on literature data.
2. Collect soil and plant related data in commercial fields to develop robust equations and algorithms for user version of the program.
3. Compare irrigation and fertigation management recommended by the program with grower's practices in a replicated trial at UC Davis' Russell Ranch.
4. Evaluate the program in monitoring fields in close collaboration with participating growers.
5. Develop the user version of CropManage based on the data collected and feedback received in objectives 2 through 4.
6. Conduct outreach activities and organize training workshops for growers and consultants.

E. Work Plans and Methods

1. Work Plan

Task 1 (objective 1): Create a test version of CropManage for processing tomatoes

The project team (PI and collaborators) will work with UC ANR programmers who are already working on CropManage to develop an appropriate user-interface and integrate

algorithms and equations specific to processing tomatoes into CropManage. Data from published research will be used to develop equations and algorithms for the test version (see C5 "Related Research"). The literature review will focus on drip irrigated systems. With roughly 90% of processing tomatoes now produced under drip irrigation, a version for furrow irrigated tomatoes would hardly justify the time and costs invested into its development.

The resulting test version of CropManage for processing tomatoes will be evaluated during the first year of the project.

Task 2 (objective 2): Monitor fields to generate a dataset for the calibration of CropManage

Data will be collected during the 2016 and 2017 tomato growing seasons in commercial processing tomato fields located in the Sacramento Valley, the northern San Joaquin Valley (Stockton area) and the central San Joaquin Valley (Fresno area). The sites will be selected to represent a wide range of soil types. Fields planted with one of the top three varieties will be preferred and fields with traditional 60-66-inch beds as well as fields with 80-inch beds will be included. Furthermore, we will deliberately include fields with high yield potential. Different fields will be monitored in 2016 and 2017.

These monitoring trials serve multiple purposes, which are crucial for the success and acceptance of the final version of CropManage for processing tomatoes:

- The collected data will be used to complement the existing datasets from previous research which was used to create the test version. Generating additional data is necessary, as some previous research has been carried out in a geographically limited area. The field trials proposed here will be carried out in different regions of the Central Valley, from the Sacramento Valley in the north to the Fresno region in the south. Collecting data from regions with different climatic conditions and soil types will allow fine-tuning the program and ensures that relevant factors related to climate and soil will be included in the program. In addition, existing datasets may not include all the parameters needed to create an accurate version of CropManage for processing tomatoes.
- The test version shall be used by the growers while the trials are being carried out. The growers' feedback will be an important input for revisions of the test version. To be used by a large number of growers, the final version needs to be user-friendly, intuitive and able to provide the information growers need (see Task 4).

The trials will be used to test the accuracy of the test version, create the final version and to detect cases where further improvements are needed (see Task 5).In each of the three regions, one field per year will be selected for intensive monitoring, while one or two fields will be selected for less intensive monitoring. The following measurements will be taken in predetermined areas of the intensively monitored fields (for a detailed description of the methods, please see section E2 "Methods"):

- Irrigation volume and timing using pulse operated water meters with cell phone connections. An inline EC meter and soil moisture sensors will be used to monitor irrigation and fertigation events.
- Canopy cover measurements will be taken using an infrared camera every two weeks until canopy closure.

- Aboveground biomass and N concentration in vines and fruit will be determined approximately every 4 weeks (week 4, 8, 12 and at harvest) to generate a N uptake curve.
- Aboveground biomass sampling will be combined with leaf total N and K diagnostic sampling and soil nitrate measurements in the top 2 feet of the profile in 1-foot increments.
- Pre-transplant and post-harvest residual soil nitrate content and distribution will be determined to a depth of 3 feet. Separate samples will be taken at a distance of 6, 12, and 18" from the drip line. The samples will be divided into 5 layers of depth (0-4, 4-12, 12-20, 20-28, 28-36 inches) for a total of 15 samples. Each sample will be a composite of 5 locations in the same field. The pre-transplant and post-harvest samples will be taken in the same part of the field. The samples will be kept cool until analyzed for nitrate, ammonium, EC and soil moisture in the laboratory.
- Soil samples taken in spring will also be used to characterize the soil at the sites. Measurements will include soil organic carbon, total N, available K, pH, and soil texture.
- Field specific information, including N fertilization records, planting date, and previous crop will be collected in collaboration with the growers. Grower interviews will be conducted to discuss their philosophy of irrigation and N management (see Task 5).

Soil and plant tissue K analyses will be done to ensure that K is not the limiting factor. Recent work has shown that K deficiency is reasonably common and yield limiting (Miyao and Davis, 2014).

To widen the scope, less intensive monitoring will be done in one or two additional fields in each area. Measurements will include repeated canopy cover measurements, yield and N uptake, as well as harvest N removal rate. Residual soil nitrate in the top two feet of the profile will be determined pre-transplant and post-harvest. Information on timing and amount of N and water applications will be collected in collaboration with the growers.

The data generated will be used to build the database for CropManage and to construct a partial N balance.

Task 3 (objective 3): Replicated field trial at Russell Ranch

Replicated trials with several irrigation and N fertilization treatments are logistically very challenging to carry out in growers' fields with drip irrigation. For this reason a replicated trial will be conducted on a 1-acre field at UC Davis' Russell Ranch, located west of Davis during year 2 and 3 of the study. The trial will compare different irrigation and fertigation rates and their effect on yield, N uptake and N use efficiency. Soil and plant analyses will be conducted at regular intervals as described above for the intensively monitored fields.

This trial will allow investigating the effects of CropManage recommendations on yield, N uptake and N use efficiency in a controlled replicated trial, allowing quantification and statistical analysis of the potential benefits of using CropManage for processing tomatoes. This important step helps ensure that the program will be considered credible by the industry.

Two N application rates and two irrigation rates will be included. One N and irrigation rate will be based on recommendations by CropManage for processing tomatoes (N_{CM}, I_{CM}). The second N and irrigation rate will be based on the growers' practices or be at least 25% above the recommendations by the program (N_G, I_G).

Each combination of N and irrigation rates will be tested in a full factorial design, with the treatment combinations being a) N_{CM} I_{CM}; b) N_{CM} I_G; c) N_G I_{CM}; d) N_G I_G. With 5 replicates, this will result in 20 plots, each being 3 beds wide and 30 m long.

The trial will be continued during the third year of the project in the same field. The treatments may be adjusted based on the results obtained.

Task 4 (objective 4): Evaluation of the tool developed in collaboration with growers

During the first and second year of the project, CropManage will be evaluated in commercial fields with intensive monitoring. Site-specific data and management practices will be entered into the program. The program will be used in close collaboration with the growers to get their feedback about the user interface and the capabilities of the tool. The irrigation and fertigation schedules recommended by the tool will be discussed with the growers.

The use of drip irrigation makes the establishment of small test plots with different management practices logistically very challenging. With processing tomatoes being a high value crop grown under drip irrigation in large fields, sub-optimal irrigation or fertigation management can result in large losses, when yield is reduced. For these reasons, participating growers will not be asked to manage their fields based on the recommendations by CropManage. However, the recommendations made by the program will be evaluated in collaboration with the growers on a regular basis and their reasons to follow or chose different management practices will be discussed. These discussions will provide valuable insight into potential limitations which may lower the adoption rate of CropManage by growers and will direct future outreach or research activities designed to address these limitations.

Task 5 (objective 5): Develop user version of CropManage for processing tomatoes

The data collected during year one will be used to improve algorithms and equations of CropManage.

After the second year of the project, the data collected in the field will be incorporated to further improve equations and algorithms. In addition, the user interface will be improved based on the experience gained with the test version during the first two years of the project.

Task 6 (objective 6): Organize and carry out training workshops

Training sessions for growers and consultants will be offered at different locations during winter 2017/18. During these sessions, CropManage for processing tomatoes will be introduced and participants will be trained in the use of the program. In addition, follow-up meetings will be held during the growing season to address problems and questions. A survey will be carried out in fall 2018 to receive feedback from the participants about their experience.

Training sessions for growers and consultants will be repeated in winter 2018/19 and training and information events will continue beyond the projects duration depending on interest and need.

Task 7 (objective 6): Outreach activities

The results will be presented at several meeting venues. Project team members will be involved in presenting research results through oral presentations at workshops and seminars and in newsletters and articles. We anticipate that a minimum of 6 presentations will be made during years 2 and 3 of this project.

The results will also be used to update the online fertilization guidelines hosted on the FREP website.

Overview of tasks and completion dates

Obj.	Task	2016				2017				2018			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1	1. Create a test version of CropManage												
2	2. Field data sampling												
3	3. Replicated field trial												
4	4. Evaluate CropManage in grower's fields												
5	5. Develop and improve CropManage												
6	6. Grower training, follow-up meetings												
6	7. Outreach activities												

2. Methods

- Irrigation volume and timing will be determined using pulse operated water meters with cell phone connections. An inline EC meter and soil moisture sensors will be used to monitor irrigation and fertigation events.
- Canopy cover will be measured with an infrared camera every two weeks until canopy closure.
- Aboveground biomass and N concentration in vines and tomatoes will be determined approximately every 4 weeks (week 4, 8, 12 and at harvest). Four to six representative whole plants will be harvested for determination of total aboveground dry biomass and N content. Once fruit begin to develop, plants will be segregated into vine and fruit samples. On the final sampling date, just before harvest, fruit yield from an additional eight plants per field or plot will be measured to ensure accuracy. Fruit will be graded to determine marketable yield (intact red fruit). Plant tissue will be oven-dried at 65 °C and ground for analysis. Total N will be determined by dry combustion (Nelson and Sommers, 1996, Bremner, 1996).
- Leaf total N diagnostic sampling will be done by collecting recently matured leaves for analysis of total N content by dry combustion.

- Soil samples for ammonium and nitrate determination will be taken with a soil probe, sieved (2 mm) and kept cool until analysis. Samples will be extracted with 2 M KCl solution and the nitrate and ammonium concentrations will be determined colorimetrically (Verdouw et al., 1978; Forster, 1995, Doane and Horwath, 2003).
- Pre-transplant and post-harvest residual soil nitrate content and distribution will be determined to a depth of 3 feet in the intensively monitored fields and the plots of the replicated trial at Russell Ranch. Separate samples will be taken at a distance of 6, 12, and 18" from the drip line. The samples will be divided into 5 layers of depth (0-4, 4-12, 12-20, 20-28, 28-36 inches) for a total of 15 samples. Each sample will be a composite sample from 5 locations in the same field. The samples will be kept cool until analyzed for nitrate, ammonium, EC and soil moisture in the laboratory.
- Soil organic carbon and total N will be analyzed by dry combustion (Nelson and Sommers, 1996, Bremner, 1996). Soil texture will be analyzed using the pipet method (Gee and Bauder, 1986), EC in a saturated paste and pH will be determined in a 1/2.5 soil:water suspension (Thomas, 1996). Soil moisture will be determined by drying samples for 24 h at 105 °C.
- Field specific information, including N fertilization records, planting date, previous crop, and soil type will be collected in collaboration with the growers.
- Grower interviews will be conducted to discuss their philosophy of irrigation and N management (see Task 5).

F. Project Management, Evaluation, and Outreach

1. Management

The project team (PI and collaborators) will meet at least once a year to coordinate activities, discuss the progress made and make adjustments to the work plan when necessary. The project team will plan and coordinate outreach activities and develop the program for training workshops.

The PI will oversee field work, lab analyses and data management. He will organize team meetings, analyze data, write progress and final reports and lead the preparation of publications.

The collaborators in the Central Valley will contact growers, select field sites in their area and serve as the main contact between the project team and the participating growers. They will also organize the local outreach events and training sessions for growers.

Tim Hartz will advise the team during all phases of the project. His experience with processing tomatoes and CropManage will be very valuable for planning and carrying out the project. Mike Cahn will serve as the main contact between the project team and the ANR programmers and support the team with CropManage related issues.

2. Evaluation

A major milestone of the project is the release of CropManage for processing tomatoes. We expect to release a version of CropManage for processing tomatoes that is ready to be used by growers in the winter 2017/18.

We expect that using the tool at the replicated trial at Russell Ranch to guide irrigation and fertigation decisions will result in significantly increased water and N use efficiency without reducing yield compared to grower practices.

The success of the project will also be determined by the number of growers and consultants attending the training workshops and the number of people registering to use CropManage for tomatoes. We expect that a total of at least 20 growers and consultants will attend the training sessions each year and that at least 75% of the participants in 2017/18 will continue using CropManage beyond the 2018 growing season.

3. Outreach

The most important outreach activity is the development and release of a CropManage version for processing tomatoes. The program will incorporate the most recent research based information in a user-friendly decision support tool which will be freely available to growers and consultants.

Training sessions will be held to make growers and consultants familiar with the tool and problems and experiences will be discussed in follow-up meetings. Furthermore, the results will be presented at different meetings. All project participants will be involved in presenting research results through oral presentations at workshops and seminars and in newsletters and articles. We anticipate that a minimum of 6 presentations will be made during years 2 and 3 of this project.

The results will also be used to update the online fertilization guidelines hosted on the FREP website.

4. Literature cited:

Bremner, J.M., 1996. Nitrogen-total. In: Sparks, D.L. (Ed.), Methods of Soil Analysis. Part 3. Chemical Methods. Soil Science Society of America, American Society of Agronomy, Madison, WI, pp. 1085–1121.

Cahn, 2012. CropManage Overview: A web application for managing water and nitrogen fertilizer in lettuce. Available online at: http://ucanr.edu/blogs/blogcore/postdetail.cfm?postnum=8501

Doane, T.A., and W. R. Horwath. 2003. Spectrophotometric Determination of Nitrate with a Single Reagent. Analytical Letters 36 (12): 2713-2722.

Forster, JC. 1995. Soil nitrogen. In: Alef K and Nannipieri P (Eds.) Methods in Applied Soil Microbiology and Biochemistry. Academic Press, San Diego, pp. 79-87.

Gee, G.W., Bauder, J.W., 1986. Particle-size analysis. In: Klute, A. (Ed.), Methods of Soil Analysis. Part 1. Physical and Mineralogical Methods. American Society of Agronomy, Soil Science Society of America, Madison, WI, pp. 383-411.

Hanson, B.R., May, D.M., 2006. New crop coefficients developed for high-yield processing tomatoes. California Agriculture 60(2):95-99.

Hartz, T., 2009. Development of Practical Fertility Monitoring Tools for Drip-Irrigated Vegetable Production. FREP final report. Available online at: www.cdfa.ca.gov/is/ffldrs/frep/pdfs/completedprojects/06-0626Hartz.pdf

Hartz, T.K, Bottoms, T.G., 2009. Nitrogen requirements of drip-irrigated processing tomatoes. HortScience 44, 1988–1993.

Miyao, G., Davis, M., 2014. Investigation of sustaining tomato plant health and yield with composted manure. Report submitted to the California Tomato Research Institute.

Nelson, D.W., Sommers, L.E., 1996. Total carbon, organic carbon, and organic matter. In: Sparks, D.L. (Ed.), Methods of Soil Analysis. Part 3. Chemical Methods. Soil Science Society of America, American Society of Agronomy, Madison, WI, pp. 961–1010.

Taylor, R., Parker, D., Zilberman, D., 2014. Contribution of University of California Cooperative Extension to Drip Irrigation. ARE Update 18(2), 58. University of California Giannini Foundation of Agricultural Economics.

Thomas, G.W., 1996. Soil pH and soil acidity. In: Sparks, D.L. (Ed.), Methods of Soil Analysis. Part 3. Chemical Methods. Soil Science Society of America, American Society of Agronomy, Madison, WI, pp. 475-490.

USDA NASS. Quickstats. Available online at http://quickstats.nass.usda.gov/ (accessed, January, 2015)

Verdouw, H., van Echteld, C.J.A., Dekkers, E.M.J., 1978. Ammonium determination based on indophenol formation with sodium salicylate. Water Research 12, 399–402.

G. Budget Narrative

Salaries and benefits

- Field work, lab analyses and data management will be done by a junior specialist who will work full time on the project, starting on April 1st, 2016 until December 2018. The annual salary for 2016 is $ 36,432, the annual increase for 2017 and 2018 is expected to be 5%. For 2016, we only request a salary for 9 months: $ 27,324. Benefits for a junior specialist are 38.9%.
- Salaries for student assistants ($9.50/h) are requested to help with pre-pant soil sampling, tomato harvest and lab analysis of the samples. We request three weeks of salary (20 h/week) in spring and fall of the first and second year for a total of 6 weeks per year. Benefits for student assistants are 1.3%.

Supplies

- Supplies include laboratory expenses, such as reagents and disposable material (e.g. cuvets, Pipet tips, tin capsules) for nitrate and total N analyses of soil, plant and water samples, as well as analyses for soil characterization. We request $ 2,400, $ 900, and $ 400 for 2016, 2017, and 2018, respectively.
- For each of the three intensively monitored fields (year 1) and the replicated trial (year 2) we request funding for a cell phone modem (Raven XTG, Campbell Science, $ 400) with antenna and mounting kit. The data plan for the cell phone is expected to cost $ 25 per month and is needed for 6 months each year ($ 150 per year).

- For each of the three intensively monitored fields two soil moisture sensors will be installed in year 1 (Echo 10HS, each $ 105). The soil moisture sensors will be bought with funding from the PI's startup package.

Equipment

The following equipment is required:

- For each of the three intensively monitored fields one flow meter with pulse output (Magmeter GPM/GT/10/p, SeaMetrics, $ 1,340), one datalogger (CR200, Campbell Science, $ 1,000) with enclosure, solar panel and battery will be required in year 1. The dataloggers will be bought with funding from the PI's startup package.
- One infrared camera (Canon T4i 650D 18.1Megapixel Vegetation Stress Camera) including lens, shutter release, pole and bag: $ 3,800. The camera is needed for canopy cover measurement and will be purchased in year 1.
- Drip material, including installation, for the replicated trial Russell Ranch is estimated to cost $ 3,000 in the second year. Soil preparation, crop management, transplants and fertilizers are estimated to cost $ 2,500 in the second and third year.
- For the replicated trial, a flow meter ($ 1,340) will be installed in the second year. The datalogger will be bought with funding from the PI's startup package (year 2).

Travel

- We estimate that each field site will be visited six times for sampling purposes during the first and second year. We estimated a distance from Davis of 30, 100 and 180 miles for the sites in the Sacramento Valley, the Stockton area and the Fresno area, respectively. A cargo van from fleet service ($46 per day, $0.209 per mile) will be used in spring and fall, and a sedan for the in-season sampling ($50 per day, $0.146 per mile).
- In addition, we estimate travel costs to Russell Ranch to be $ 200 in the second and third year of the project. The cargo van will likely be used every year for two half days, the sedan will be used 6 times each year for two hours each time. The distance to Russell Ranch is approximately 8 miles one way.
- We also request an average of $ 500 per year for the PI and each collaborator to visit participating growers, to travel to team meetings, growers meetings and other outreach events. This sum is based on the rates for a sedan from fleet service ($50 per day, $0.146 per mile) and includes using the car for 5 full days (5 * $50), driving 616 miles (616 * $0.146) and staying at the meeting location overnight twice (2* $80).

Professional/Consultant Services

CropManage is hosted by University of California Agriculture and Natural Resources (UC ANR). During the first year of the project in early 2016, ANR programmers will develop the test version of the program including creating an appropriate user interface and populate the program with equations and algorithms based on literature data.

During the second and third year, the programmers will improve and update the equations and algorithms based on the field data generated and improve the user interface if needed. In

addition, in the third year, the user interface will be improved based on the experience gained with the test version during the first two years of the project.

We expect that these tasks will require 180 hours of programming in 2016, and 20 hours in 2017 and 80 hours in 2018. At a rate of $ 85/hour, programming will cost $ 15,300 in 2016, and $ 1,700 in 2017 and $ 6,800 in 2018. Over the period of three year, the total cost for programming is $ 23,800.

Indirect Costs: (Accounted for in the "Other Expenses" line)
Per a California Department of Food and Agriculture Memorandum (Dated April 10, 2014) all research and grant contracts with universities will be subject to an F&A rate of 10% of personnel costs. This rate has been confirmed by Doug West at FREP in an email on 2/25/15.

Other funding sources

Soil moisture sensors and dataloggers will be purchased with funding from the PI's startup package. The startup package will also cover part of the supplies required for laboratory analyses (approximately $ 500 per year).

I. Appendices

1. Project Leader

Resume and list of recent publications from

- Daniel Geisseler

2. Cooperators

Letter of support form

- Tim Hartz
- Gene Miyao
- Mark Lundy
- Tom Turini
- Brenna Aegerter
- Mike Cahn

3. Others:

Dave Krause, UC ANR